

Uncertainty Quantification Using Swarm Intelligence

Author:

David G. Robinson

Mailing Address:

Risk and Reliability Analysis Department
PO Box 5800, MS 0748
Sandia National Laboratories
Albuquerque, NM 87185

Contact Data:

W: 505-844-5883

E: drobin@sandia.gov

Abstract –

This paper documents research into the use of an adaptive cultural model and collective intelligence to model a virtual team of design engineers in their quest to characterize the uncertainty of a complex system. In particular the research involves the use of swarm intelligence as a means of characterizing the reliability of complex problems involving multiple most probable points. Lack of consideration of the existence of multiple solutions can lead to grossly misstating the reliability of structural systems. The particular example addressed in the paper involves determining the optimal lay-up of a fibrous composite in the presence of uncertainties in material properties and stress loading. It is desired to find the orientation of the layers that maximizes the reliability of the panel. Particle swarm methods are particularly suited to this complex optimization problem.

Particle swarm optimization (PSO) is regarded as being of the family of evolutionary strategies for problem solving. Other members of this family include, for example, genetic algorithms and evolutionary programming. While heavily influenced by the philosophy of evolutionary strategies, PSO differs significantly from these “survival of the fittest” algorithms in that it is based on a social cooperative perspective: individuals working with others in a common social group to solve problems. Contrary to the algorithms in Darwinism-based paradigms, individuals are not replaced by better performing individuals, the individuals in a swarm model adapt to the environment by gathering information and processing that information as a group. In a swarm model it is not the individual who changes, but rather the knowledge of the individual that changes from iteration to iteration.

For the problem at hand, a swarm of engineers, acting as a virtual design team, are tasked with searching out the correct fiber orientation that provides the best probability of survival for the composite panel. Beyond the solution of the problem, the animated cartoon of the design engineers as they move through design space, identifying possible solutions comparing results and developing new alternatives is quite enlightening. For those who have been involved with design teams, it can also be a bit disturbing (and humorous) in its resemblance with reality.